ARTIFICIAL INTELLIGENCE: A REVOLUTION WAITING TO HAPPEN

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Artificial Intelligence is a rapidly emerging and influential technology that seeks to develop intelligent agents that can replace or improve on human performance in many aspects of human life. The scope for implementation is vast, and the world's leading technology is based not in the military, but the civilian sector.

Historians have provided a context for understanding dramatic changes in the military, and have categorized this change by external and internal drivers. The Military Revolution and Revolution in Military Affairs are used as a vehicle to provide context to the emerging properties of Artificial Intelligence research.

Analysis of AI is exams the related but significantly different theories of General and Narrow AI. At the current level of research, it is clear that Narrow AI has potential to develop into many important RMAs, limited by innovative concepts and organizational desire to change. General AI, on the other hand, looms in theoretical form as a potentially significant change to the social-military order.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

ARTIFICIAL INTELLIGENCE: A REVOLUTION WAITING TO HAPPEN, by Major Stephen James Karl Bates, 88 pages.

Artificial Intelligence is a rapidly emerging and influential technology that seeks to develop intelligent agents that can replace or improve on human performance in many aspects of human life. The scope for implementation is vast, and the world's leading technology is based not in the military, but the civilian sector.

Historians have provided a context for understanding dramatic changes in the military, and have categorized this change by external and internal drivers. The Military Revolution and Revolution in Military Affairs are used as a vehicle to provide context to the emerging properties of Artificial Intelligence research.

Analysis of AI is exams the related but significantly different theories of General and Narrow AI. At the current level of research, it is clear that Narrow AI has potential to develop into many important RMAs, limited by innovative concepts and organizational desire to change. General AI, on the other hand, looms in theoretical form as a potentially significant change to the social-military order.

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I would like to first acknowledge the many historians and academics that have contributed to the ideas of Military Revolution and Revolutions in Military Affairs which provided the inspirations to look forward in an attempt to make sense of potential changes in the military.

I am thankful for the patience and quiet motivation provided by my committee and the encouragement to continue with and persevere in completing an MMAS at Command and General Staff College, I have thoroughly enjoyed discussing the topic of AI in the military and wish there was more time to include all observations and ideas that have been developed as a part of this research.

I wish to acknowledge my brother, Christopher Bates who is a post graduate student in Artificial Intelligence at Georgia Tech for taking the time to read, critique and correct my interpretation of AI development in the military.

Finally, I wish to acknowledge all the authors of my childhood, but in particular, William Gibson who's novel Neuromancer inspired a lifelong obsession with computers, reason, and artificial intelligence.

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ACRONYMS

AI	Artificial Intelligence
DARPA	Defence Advanced Research Projects Agency
IT	Information Technology
ML	Machine Learning
MR	Military Revolution
RL	Reinforcement Learning
RMA	Revolution in Military Affairs

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CHAPTER 1

INTRODUCTION

Command is an art that depends on actions only humans can perform.
— ATP 3-90.5, *Combined Arms Battalion*

Will Artificial Intelligence (AI) cause a Revolution in Military Affairs (RMA) or a Military Revolution (MR)?

Introduction

As the world enters the seventh decade after the invention of the integrated circuit, continued advances in the power and mobility of computer hardware, coupled with advances in theory and application of AI, Robotics and Control Theory are challenging the primacy of human beings in many aspects of everyday life.

The scientific fields of Artificial Intelligence, Robotics, and Control Theory are already pervasive in the fabric of the digitized and automated world in which we live. As a combined technology, they have the potential to replace the human worker, from the mundane to the most delicate task of neurosurgery. As technology continues to advance, the decisions we make as governments, and societies in general, will guide the implementation and impact of intelligent technology, these, in turn, will determine the future implementation in warfare.

Background

Historians, academics, and writers have developed many theories of evolution or revolution in warfare. While the terms Military Revolution (MR) and Revolution in Military Affairs (RMA) are semi-defined, and rarely agreed on, the magnitude of the

difference has a significant bearing on the impacts felt by society. By this measure alone, the MR has profound societal changes, whereas the RMA may profoundly affect the conduct of war, with little consequence for societal change.

Historians have often defined a period of modern history by the dominant technology of the time. The Industrial and Nuclear ages, and most recently the Information Age are examples of such technological driven periods in modern history. The technological developments of each of these ages have had profound impacts on all aspects of modern society, and the age we are living in will be influenced by the continued developments in Industrialization, Nuclear, and Information technology.[1] Despite the changes, the impact of technology and progress has been distributed over time so as to smooth out disruption to society naturally.[2] From theory to practice technology can take several decades or centuries to develop and be realized, but when the conditions are right, the emergence of new technology can be dramatic. In the fields of Computer Science and Artificial Intelligence, the theory of accelerating returns makes the probability of disruptive occurrence more likely.

A phenomenon is known as the law of accelerating returns, a theory put forward by Ray Kurzweil,[3] describes a technology that improves proportionally to how good the

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[1] Williamson Murray, *America and the Future of War* (Stanford, CA: Hoover Institution Press, 2017), 63.

[2] Steven M. Leonard, "Inevitable Evolution: Punctuated Equilibrium and Revolution in Military Affairs" (Monography, School of Advanced Military Studies, Ft Leavenworth, KS, 2001).

[3] Murray Shanahan, *The Technological Singularity* (Cambridge: The MIT Press, 2015), xviii.

technology is. The better technology is, the faster it gets better, yielding exponential improvement over time. A prominent example of this is Moore's Law, which has continued to hold true for several decades and specifically relates to the density of transistors on a computer chip.[4] Acknowledging that any exponential technology must plateau eventually, due primarily to laws of physics, it is possible to imagine the accelerated growth in Artificial Intelligence may result in human equivalent or better intelligence before reaching a limiting physical plateau.

If this conjecture is indeed true, it is then a small leap of faith to envisage Artificial Intelligence being capable of replacing Humans in many aspects of life, from peaceful work to the incorporation and reliance on autonomous systems for the conduct of the industrial and military activity.

Scope

The scope of this thesis is restricted to case studies that demonstrate and illuminate the complexity of rapid emergent technology in the field of artificial intelligence. By understanding the current state of technology, research, and limitations within the field of Artificial Intelligence and the associated impact of Robotics and Control Theory,[5] this thesis aims to inform and advise the formulation of policy and implementation strategies for Artificial Intelligence.

[4] Ibid.

[5] Robotics and Control Theory are discussed as they relate to AI.

Importance

Dimensions of national power have long been synonymous with the development of the national strategy. Nation states implement and employ national power based on the perceived strength of their position amongst friends, allies and adversaries alike. While strategists have developed the concept of Diplomatic, Informational, Military, and Economic power to describe how a nation can influence national objectives, the fundamental input and output within each pillar has been the result of the action of a nation's primary resource the human being. The possibility to replace the human offers a myriad of developments that may affect concepts of national power and therefore may change the balance or strategies necessary in a future with artificial agents.

While this study applies to Artificial Intelligence as the main focal area, the method or characteristics of the RMA and MR are equally applicable to other technology and can be used to assess the potential of any given technology. By mapping the common characteristics of technology based RMAs, it would be possible to make similar determinations on emerging technology. An example would be to analyze Quantum Radar theory and determine the threat it poses to United States stealth technology.

Writers on RMAs and MR make some general observations on the importance of understanding these phenomena, and its application to military theory. For the military that is currently regarded as the most capable, ignoring RMAs can lead to vulnerabilities or in extremes a complete reversal in capability. Writers on RMAs point to several key considerations for their study. First, that one should anticipate one or more competitors

seeking to exploit technology to gain military advantage,[6] (i.e. monopolies are transient in so much as they exist until someone decides to break them up). Second, continued technological dominance and leadership are not assured, history demonstrates the rapid shifting in dominance, and the rise of niche competitors.[7] Third, competitors may not follow the same path or technology trees leading to asymmetric capabilities[8] and Fourth, critically for wealthy nations; not all military revolutions prove cost prohibitive to smaller competitors.[9]

Primary Research Question

The primary research question is Will Artificial Intelligence cause a revolution in military affairs or a military revolution. The reason for the distinction between RMA and MR is that the level of development and concern required of a government in assessing and implementing change is proportional to the expected social, technical and ethical impacts of the MR or RMA. Understanding the potential for change caused by AI can inform policy makers as to the risk in any potential development strategy. Further analysis of the current military interest in Artificial Intelligence in contrast to the level of disruption expected may inform the decision for funding, implementation, and policy.

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[6] Knox Macgregor and Willaimson Murray, eds., *The Dynamics of Military Revolution: 1300-2050* (Cambridge: Cambridge University Press, 2001), 12.

[7] Ibid.

[8] Ibid.

[9] Andrew Krepenvich, "Cavalry to Computer; The Pattern of Military Revolutions," *The National Interest* no. 37 (Fall 1994): 11.

Secondary Research Questions

To answer the first question, it is necessary to develop a framework of meaning for Revolutions in Military Affairs and Military Revolution. During the 1980s to 2000s significant writing and research was conducted to describe these phenomena. To this end, the secondary questions are, what are the characteristics of an MR, what are the characteristics of an RMA. Which leads back to the primary research question, how does Artificial Intelligence compare with the characteristics of Revolutions in Military Affairs and Military Revolutions?

Definitions

Artificial Intelligence (AI)–The field of science that aims to understand and build intelligent entities.[10]

Control Theory–The theory of control systems in animals and machines.[11]

DIME–The elements of national power, Diplomacy, Information, Military, and Economic.

Machine Learning–An algorithm that learns from example, (i.e. given input and outputs it learns the rules to get from one to the other), is distinct from regular programming in which the programmer give inputs and set of rules from which the algorithm produces output.

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[10] Peter Norvig and Stuart Russell, *Artificial Intelligence: A Modern Approach*, 3rd ed. (Edinburch Gate: Pearson Education, 2016).

[11] Norbert Weiner, *Cybernetics: Or Control and Communication in the Animal and the Machine,* 2nd ed. (Cambridge: The MIT Press, 1961).

Military Revolution (MR)–A military revolution defining feature is that it fundamentally changes the framework of war. It is sudden and occurs due to vast societal change as opposed to originating from within the military.[12]

Narrow or Weak AI–Artificial Intelligence system designed to solve a particular cognitive task (e.g. planning a traffic route).

Neural Network–A particular type of machine learning algorithm that has gained much interest in recent years due to its ability to learn very complex rules given enough computing resources (e.g. semantically labeling objects in photos, transcribing speech audio into text, etc.).

Revolution in Military Affairs (RMA)–RMAs are lesser transformations that appear susceptible to human direction, and in fostering them, military institutions that are intellectually alert can gain a significant advantage.[13]

Robotics–A machine that replaces or augments the activity of human beings.

Strong or General AI–General Artificial Intelligence that can adapt to any cognitive task. In literature, it is assumed the development of a Strong AI would be at the human level or better.

Assumptions

This thesis assumes that human-like or better Artificial Intelligence is a theoretical possibility, and until there is a scientific proof otherwise, it must be considered when discussing the future of this field.

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[12] Macgregor and Murray, 1.

[13] Ibid.

It acknowledges the work of theorist on RMAs and MR and that it is possible to map characteristics of these phenomena.

It assumes that there is sufficient technical understanding in the current capability of narrow AI to make a determination as to its likely impacts on society and the military.

Limitations

A significant limitation of the study is the emergent nature of the technology. This thesis looks to the future to inform policy and pathways to harness the technology represented by Artificial Intelligence. A significant example exists in the historical record and the current state of research, however; some underlying hypothesis, particularly in the field of general AI, are yet to be proven.[14] While this does not devalue the analysis of the current research, it suggests that continued monitoring will be necessary to remain informed of the potential development in the field.

There exist two distinct fields in Artificial Intelligence, General, and Narrow [15] sometimes referred to as Strong and Weak. Strong AI has the greater potential for change, but at this time is entirely theoretical in nature. Therefore, the focus of the research will be on Narrow AI applications, which are already manifest in the world, with only the necessary discussion of general AI to demonstrate future change.

In this way, the paper will serve to inform decision making for contemporary policy makers.

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[14] Norvig and Russell.

[15] Ibid.

Delimitations

The level of comparison required to do a detailed analysis of the Industrial and Nuclear revolutions would exceed the time available and scope of this thesis, with the primary goal being to analyze Artificial Intelligence. This is mitigated by the use of authors who have researched and discussed RMA and MR in relation to both the industrial and nuclear revolutions. In doing so, and using them as the framework for analysis, it would be logical that any analysis of Industrial and Nuclear revolution would be positively biased for those frameworks.

The second delimitation is to utilize the policy documentation from the United States as it provides a transparent and public debate of autonomy and force structure implementation. It also acknowledges the belief that United States research both commercial and the military is at the forefront of AI development.

To make sense of Chinese, Russian, or even Indian military development it would require more detailed analysis of similar technology and is worth of a study in its own right. A fundamental problem with assessing AI development is that it is not visible to the casual observer, watching a robot walk for instance and then being able to tell what style of learning method was used, is only possible if one has access to the programming and expertise in programming which the author does not possess.

CHAPTER 2

LITERARY REVIEW

The literary review is designed to give the reader a broad understanding of the three main topics, Military Revolution, Revolution in Military Affairs and Artificial Intelligence.

Military Revolution and the RMA serve as the framework for understanding the impact of technology. The purpose here is not to chase the next big thing, but rather critically look at the historical impact of technology on warfare and use it as a lens through which to study emergent technology. The choice of Artificial Intelligence is deliberate, as we become evident in the review, it is a technology that is rapidly improving and being implemented across many aspects of modern society.

A great deal of work was completed in the 1990s with regards to the phenomena of Military Revolution and RMAs, and towards the idea that the United States was undergoing an RMA in the post-Gulf War period.

Theories on Military Revolutions and Revolutions in Military Affairs

In the *Dynamics of Military Revolution 1300-2050*, the authors suggest that two very different phenomena have been at work over the past centuries: "military revolutions," which are driven by vast social and political changes, and "revolutions in military affairs" which military institutions have directed.[16] The relevance of these distinctions is in the magnitude of the effect and the origin of the phenomena. Several

[16] Macgregor and Murray, 12.

prominent authors provide theories on MRs and RMA and the nature of their essential character and are summarized below.

Theory of Revolutions in Military Affairs and Military Revolutions

Marshall Nikolai Orgakov

In the 1980s Marshal Nikolai Orgakov recognized what he called the military-technical revolution. What could be considered a Russian take on RMA, Orgakov warned the Russian politburo that if the USSR failed to match the United States technical dominance, the United States would establish a superior fighting force by the mid-1980s. His theory characterized the United States as "synthesizing new technologies, evolving military systems, operational innovation and organizations adaptation into a whole that was more powerful than the parts."

Orgakov recommended that the USSR need to downsize its military, reorganize along improved technology and structure to counter the military advantages of the USA. While Orgakov was ultimately sidelined from political influence, and yet his ideas were partially confirmed by the decisive nature of the United States war in Iraq in 1991. While the comparison between Iraq and Russian capability requires a significant leap, the overwhelming success of United States military power in the Gulf is self-evident and was the genesis for prolific writing on Military Revolutions and RMAs.

Alvin and Heidi Toffler

In their work, *War and Anti-War*[17] the Tofflers are critical of the often sweeping use of the term Revolution. Their main argument with regards to Military Revolution is that it is bound to the generation of wealth. They argue that there have been only three revolutions in the history of warfare, and all are associated wealth generation. The first occurred in the agrarian culture as land ownership became valuable, the Toffler's argue that humans waged war for control of land as was the primary producer of wealth in the first wave. The second wave was the industrial revolution, which paralleled mass-production with mass destruction, here resources for manufacturing were more important than land and drove the nature of conflicts both regarding the military strategic value of resources and mass produced weapon systems. The third wave they contend was the transition to an information economy, where knowledge and smart business practices were primary, and there followed a corresponding transition from mass warfare to smart warfare. They characterize this transition by the de-massification of military forces to smaller and yet more capable units. The Toffler viewpoint is very specific but demonstrates the generalist nature of true revolutions, societal change.

Andrew Krepinevich

Andrew Krepinevich is considered one of the foremost thinkers on Military Revolutions and in particular the nature of the post-gulf war revolution, with wich much of the current literature is concerned. Significant to this thesis is that Krepinevich in his

[17] Alvin Tofler and Heidi Toffler, *War and Anti-War: Making Sense of Today's Global Chaos* (New York: Little, Brown and Company, 1993).

work *Cavalry to Computer*[18] provides a framework for characterizing military revolutions.

Krepinevich alludes to the belief that post-1991 the United States may have been in the midst of a military revolution, and sets out to identify a pattern in the military revolution to support this hypothesis. Some of Krepinevich significant insights are as much about the role of organizations and the military in embracing and generating change, and the potential costs of ignoring technology and organizational change while an adversary embraces it.

Krepinevich defines a military revolution as the application of new technology into a significant number of military systems combined with innovative operations concepts, organizational adoption in a way that fundamentally alters the character of conflict. To do this, it must create a dramatic increase in combat potential and effectiveness of armed forces.[19]

Krepinevich identifies ten revolutions that meet the requirements of his definition starting from the Hundred Years' War (1337 to 1453) through to the modern day.

Williamson Murray

Williamson Murray makes a distinction between the MR and the RMA, in particular, like the Toffler's distinguishes an MR from RMAs as part of wider societal upheaval, and that the RMA which is of military genesis, tends to follow in the wake of the MRs as a series of military advances. RMAs always occur within the context of

[18] Krepinevich.

[19] Ibid.

politics and strategy–and that context is everything.[20] Logically it flows that RMAs will follow in the political and strategic aftermath of an MR, but with regards to peacetime innovation, the conclusion is that nations with a political or strategic necessity will continue to drive RMAs. Williamson Murrays most recent work (Murray, America and the Furture War 2017) includes the Information Revolution as a sixth social-military revolution; this newer phraseology helps understand and distinguish MR from the RMA and also hints at the differing magnitude of various MRs.

Williamson Murray and MacGregor Knox were acknowledged earlier in their work *Dynamics of Military Revolution* which provided the author the original concept of trying to understand MR and RMAs in a forward-looking sense.

Williamson's major distinction that is relevant to this thesis is the cause of; and magnitude of the effect of an RMA or MR. Clifford Rogers who follows provided a counterpoint to the causal relationship between MR and RMA.

Clifford Rogers

Clifford Rogers[21] provides a different view on Military Revolutions and RMAs. Rogers makes the distinction that RMAs precede rather than follow Military Revolutions, Technology with wide-ranging social, economic and political influence can manifest as an RMA, the example being the Artillery revolution which changed offensive and defensive nature of warfare, but also changed the established balance of power in Europe

[20] Macgregor and Murray, 180.

[21] Clifford J. Rogers, ed., *The Military Revolution Debate Readings on the Military Transformation of Early Modern Europe* (Boulder, CO: Westview Press, 1995), 299-333.

and wrought deep social changes. This position has the Artillery Revolution as an RMA precede and drive the rise of nation states or the generally accepted Military Revolution that occurred because of the Artillery Revolution.

Rogers provide questions that can be used to gain insight if an RMA is to precede a Military Revolution. Does the RMA require a military change in direction or is it "the same only more so?" Does it alter the balance between the offense and the defense? Does it modify the components need to assess a nation's military strength? To what extent will it require changes in social, economic and political structures, not just military ones?

Colin Gray

Dr. Colin Gray has attempted to make sense of the debate of RMAs and associated theory, in *Recognizing and Understanding Revolutionary Change in Warfare: The Sovereignty of Context* rather than debate the various views on RMA Gray asks the question of whether the theory has any useful purpose. Especially given the 1990s attraction to RMA theory.

By and large, the RMA process and the idea of revolutionary change, what is more often referred to as transformation in the post-RMA era, survives analysis. Gray makes seven significant finding when dealing with and understanding RMA these are: Context matters–he studies six contexts, (1) the political, (2) the strategic, (3) the social-cultural, (4) the economic, (5) the technological, and (6) the geographical. While all are vital the political is the driver for war, its context and occurrence are political.

Revolutionary change in warfare may be less necessary to revolutionary changes in social attitudes to war.

There are necessary conditions for carrying through a revolutionary change in warfare; he summarizes them using the Murray Knox definitions as being the most complete analysis, to date:

First, that "technology alone has rarely driven them; it has functioned above all as a catalyst." Second, they argue that revolutions in military affairs have emerged from evolutionary problem-solving directed at specific operational and tactical issues in a specific theater of war against a specific enemy.

Third, the editors claim that "such revolutions require coherent frameworks of doctrine and concepts built on service cultures that are deeply realistic. Innovation, to be successful, must rest upon a thorough understanding of the fundamentally chaotic nature of war." Fourth and finally, they assert that "revolutions in military affairs remain rooted in and limited by strategic givens and by the nature of war. They are not a substitute for strategy—as so often assumed by utopians—but merely an operational or tactical means.[22]

Recognizing an RMA or transformation is one thing, but understanding the implications in context to geostrategic reality, i.e. generating understanding is different.[23]

When implementing an RMA, the requirement to do so with adaptability and flexibility is essential in realizing any significant advantage, too often RMAs are pursued along narrow pathways which make them vulnerable to the next observation may by Gray.

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[22] Gray.

[23] Ibid.

That an implemented RMA is cause for an adversary to search for an antidote, Eventually the antidotes triumph. They can take any or all of tactical, operational, strategic, or political forms; the mitigation is to remain flexible and adaptable[24].

Revolutionary change is only realized by the “audit of war” and then only in the context of the war's true nature. This highlights the problem, even “hubris” of predicting the outcome of an RMA.

Gray offers a detailed critic of RMA or transformation in the military and reinforces that there is still utility in the idea and that fundamentally they have occurred, and will continue to take place in the context of warfare.

Summary of Military Revolutions and Revolution in Military Affairs

Military Revolutions and Revolution in Military Affairs share many of the same characteristics, and for some researchers, there is no need to make a distinction between the two. In military terms, the exegesis of both terms results in a fundamental shift in tactics, techniques, and procedures, and stresses a requirement to adopt change or be left at a fundamental disadvantage, with the magnitude of the disadvantage being proportional to the magnitude of the MR or RMA, tempered by geostrategic realities. For the purpose of this study, the difference that is measurable is whether the change is being driven internal to military organizations, or whether it is happening externally to the military but applying an irresistible force onto the organization.

[24] Ibid.

Chapter 4 will examine various MRs and RMAs for underlying characteristics that can be demonstrated or discounted as they apply to Artificial Intelligence.

Artificial Intelligence

For thousands of years, humanity has tried to understand how we think; that is, how we can perceive, understand, predict and manipulate the world far larger and complicated than itself. The field of artificial intelligence attempts not only to understand but to build intelligent entities.[25]

Artificial Intelligence spans a variety of fields from the general (learning and perception) to the specific, such as playing chess, proving mathematical theorems, writing poetry, driving a car on a crowded street, and diagnosing diseases.[26]

From an academic standpoint, Peter Norvig and Stuart Russel's text *Artificial Intelligence: A Modern Approach* is the foundation text for the majority of tertiary education on AI. While briefly discussing the theory of general artificial intelligence it is concerned with the modern approaches to AI as it currently applies to the field.

This means that the majority of theoretical work and current application is centered within the field of narrow artificial intelligence. Programs that are designed to learn and adapt to complete specific tasks efficiently, or to perform a function better. Prominent examples in the field are systems like Deep Blue, Tesla self-driving technology, Google Search, or Amazon's logistics storage and distribution systems.

[25] Norvig and Russell, 1.

[26] Ibid.

The fact that Artificial Intelligence is highly pervasive in everyday human activity is worth acknowledging, in the modern society every interaction 'you' have in some way is influenced by a form of AI. What is it about the modern-day AI that separates the fact from the fiction we are presented with from Hollywood and Science Fiction writers.

The answer to that lies in the nature of Narrow and General AI, and while there is very little overlap at the moment between the two approaches to AI, it does not necessarily correlate that narrow AI development will not someday evolve into General AI. For the time being General AI remains a field of theory and speculation, while narrow AI is pervasive in everyday life.

General or Strong Artificial Intelligence

General Artificial Intelligence is the field of research, with the ultimate goal of developing a sentient artificial intelligence. One which is typically characterized by the ability to learn in the most general sense, and can teach itself beyond the constraints of its original conception. This form of AI is often referred to as Strong AI.

Traditionally this field has been associated with the pursuit of a sentient computer-based intelligence, and that is one of the approaches that has been pursued. In more recent history, the pursuit of non-computer based but artificial intelligence has been proposed as a pathway to general AI.

General AI is the basis for most of the ethical debate revolving around AI development. It is in the field of General AI that terms such as the Singularity Event[27] are proposed. The emergence of intelligence that is more capable than any human would if

[27] Shanahan.

possible be one of the most significant technological breakthroughs in the history of humanity.[28] It would be conceivably open up an understanding of the natural world beyond our comprehension. It is this event that some researchers have likened AI research to the modern-day Manhattan Project. For the near foreseeable future, however, the overwhelming advancements will occur in Narrow AI.

Narrow or Weak Artificial Intelligence

Artificial Intelligence as it refers to the modern scientific study is difficult to define. However, we can differentiate narrow AI from general AI, and this distinction is of practical use. The history of AI and the context is codependent on the technology that is being used to develop it. The application of any given AI is also dependent on the environment in which one places that AI and requires it to act.

The term Narrow AI implies AIs that are designed to complete very specific tasks, The goal being to develop an AI that can conduct a particular task as well as or better than most humans. Narrow AI are limited in both environment and function. One of the most prominent public examples of AI is DeepBlue which first defeated the reigning world champion Gary Kasparov in 1996. The sole purpose of DeepBlue was to play chess better than a human, and it achieved this through the use of an alpha-beta minimax search with a heuristic static evaluation function.[29]

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[28] Blay Whitby, *Artificial Intelligence: A Biginer Guide* (Oxford: One World Publications, 2012).

[29] Richard E. Korf, "Does Deep Blue use A.I" (AAAI Technical Report WS-97-04, 1997), accessed March 30, 2017, https://www.aaai.org/Papers/Workshops/1997/WS-97-04/WS97-04-001.pdf.

Figure 1. Kasparov playing DeepBlue

Source: Photo Bucket, "Kasparov Playing DeepBlue," accessed April 17, 2017, http://photobucket.com/.

Gary Kasparov remarked that it did not feel like playing a human being, so in replicating the feel of a human player, the program would have been subjectively a failure. The critical observation here is that while DeepBlue could think in chess terms, it did not think like a human. In pure output DeepBlue could not be beaten, today your mobile phone has enough computing power that given a sufficiently well-designed algorithm like StockFish,[30] it is almost impossible for a human to beat the at chess.[31]

[30] Stockfish Chess, "Open Source Chess Engine," accessed April 7, 2017, https://stockfishchess.org/.

[31] Sebastian Anthony, "A New (Computer) Chess Chamption is Crowned, and the Continued Demise of Human Grandmasters." Extreme Tech, December 30, 2014,

In modern terms, while Chess is a complicated game, it is an environment that is well defined and limited in external variables. It is fully observable in that the AI can know everything about the environment that matters to the problem at hand and can make calculations and suggest moves with very limited room for error. If one was to compare playing chess, to cleaning up the kitchen, the latter is a fundamentally more difficult task, in fact, as an AI task cleaning considered harder than automated driving.[32]

As a reader that may sound counter-intuitive, but the reason comes down to the complexity and organization of the environment. Automation through AI is more easily applied to ordered environments than to disordered ones. In the case of driving, and cleaning, humans have developed a system of rules for driving, yet unless your mother taught you to dust before you vacuum, there are few rules governing how to clean a kitchen, and yet without much thought, a human makes many decisions when cleaning that are seemingly intuitive.

Tesla Motors uses one of the most automated production systems to produce its range of Tesla Model cars, but some tasks are still completed by hand, interestingly the finishing touches, shielding, and arrangement of coils in the heart of a Tesla Car, its electric engines, are still completed by manual labor, as of yet it is not a task that is suited to automation.

Returning for a moment to the AI chess player, where DeepBlue is considered to be a simple algorithm using brute force to beat a human, the creation and success of

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accessed April 7, 2017, https://www.extremetech.com/extreme/196554-a-new-computer-chess-champion-is-crowned-and-the-continued-demise-of-human-grandmasters.

[32] Whitby.

Alpha-Go points to the current and possibly most exciting field of narrow-AI research, and that is the field of machine learning and in the case of Alpha-Go the sub-field of Deep Reinforcement Learning.

Machine Learning and Deep Reinforcement Learning

Machine Learning is essentially an approach to solving problems. This approach applies when there exists a large body of observations of interest, a belief of a relationship between the observations, but no obvious way to describe it, (i.e. we cannot solve it classically[33] or simply).

In theory, machine learning solves the intermediate steps between a start state and the desired end state by applying a learning model repeatedly until it generates the required output. It is in this way that Microsoft taught the Kinect to track and recognize human gestures for the Xbox.[34] Machine learning in the contemporary sense has made use of the vast amount of data the modern world has generated in conjunction with the information age. Machine Learning perhaps is better understood by reframing one's line of inquiry. Rather than asking what model makes sense of the data, one can ask what in the data is of use to us? In this way machine learning or one facet of it data mining allows the data to dictate the what next. Advances in machine learning and computing power

[33] Ethem Alpaydin, *Machine Learning* (Cambridge, MA: The MIT Press, 2016).

[34] David Jones, "Project Natal: Machine Learning Applied," Digital Perspectives by David Jones, March 1, 2010, accessed April 13, 2017, https://davewjon.word press.com/2010/03/01/project-natal-machine-learning-app.

have led to some of the most successful and ubiquitous technology in existence today, technology break through that have proven to be not only useful but profitable.[35]

Neural Networks and Graceful Degradation

Neural Networks are an approach to Artificial Intelligence that attempts to through simulation recreate the structure and function of the neuron. There are a couple of appealing reasons to pursue a neural net solution to AI development. The first is that by modeling the behavior of the human brain, researchers hope to develop human-like intelligence, the second is that by modeling neuron behavior, research can hope to understand the function of the human brain.

The second property of neural networks that makes them appealing to researchers is a property known as graceful degradation. In theory, a neural network that loses or has some part of the neural network damaged can continue to provide usefully, if not as well optimized output. In this way, a control system, say for instance an integrated air defense system, which is under attack and or has lost sensor input would still make useful control decisions. It is a form of an inbuilt system or process resilience that would be highly desirable in many high-performance tasks.

Advanced Artificial Intelligence

The most advanced AIs which are starting to exhibit more behavioral traits are stemming from advances in a field known as Deep Reinforcement Learning. The leading example may well be Googles DeepMind. Google purchased DeepMind Technologies in

[35] Whitby.

2014. DeepMind (formerly Alpha-Go) was the Deep RL Neural Network AI behind the successful Go competition which saw the world's best Go player defeated by a computer. This technology blurs the lines between classical Machine Learning and Neural Networks, with the company claim being that DeepMind is capable of adaption to problems outside of the original development intent, this flexible capability of an AI to learn new applications without significant modification is a huge step forward in AI research.

DeepMind is still developmental, but it has generated some interesting behavioral results. When pitted against itself in a simple Apple gathering game, both versions of the AI worked efficiently when the supply of apples was plentiful. When placed under stress, by reducing the available supply of apples, the AI developed aggressive behavior, to include the use of lasers to target the opposing AI.[36] It is these types of behavioral evolutions that fuel some of the concerns for the development of Strong AI. Most people are aware of the outspoken resistance to AI from prominent technologist and scientists like Elon Musk[37] and Stephen Hawking.[38] Their concerns are founded in the rapid pace of AI development.

[36] Deep Minds, "Understanding Agent Cooperation," accessed April 14, 2017, https://deepmind.com/blog/understanding-agent-cooperation/.

[37] Elon musk was an investor in the original DeepMind Technologies.

[38] Rory Cellan-Jones, "Stephen Hawking Warns Artificial Intelligence Could End Mankind," *BBC News*, December 2, 2014, accessed April 28, 2017, http://www.bbc.com/news/technology-30290540.

Civil Development in Artificial Intelligence

Unlike the development of nuclear weapons which occurred amid great secrecy, Artificial Intelligence research is overwhelmingly contained within the civilian sector, whether in commercial or educational institutions. Commercial adoption and development have seen the rise of some of the most profitable companies in recent time. They are of course Google, Amazon, Apple, IBM, Facebook, Baidu and more recently Tesla. All of these companies are leading the development and commercialization of AI in the marketplace. They are also competing to soak up and hire the best and brightest researchers in the field.

As we are starting to see, AI spans multiple disciplines and approaches; companies tend to develop along specific theories and techniques. Whether that is ML, neural nets, data mining, algorithms or biomimicry, AI is gathering pace as a distinct field, and also managing to influence the theories and output of other scientific fields of research.

Military Development in Artificial Intelligence

Military development of AI is particularly hard to gauge from the unclassified information that is available. Within the 3rd offset strategy,[39] AI is one of many potential technologies that is considered a fertile ground for generating military advantages. There is within Defense Advanced Research Projects Agency (DARPA) expectation for many

[39] *Statement by Arati Prabhakar, Director DARPA before the subcommittee on Emerging Threats and Capabilities Armed Services Committee, US Senate*, April 12, 2016, accessed April 7, 2017, http://www.darpa.mil/attachments/DARPA2016 SASCTestimony4-1-2016.pdf.

applications to arise from AI. One project alone within the DARPA AI research points to the difficulty in machine learning development, Probabilistic Programing for Advanced Machine Learning. This project aims to make programming ML accessible to anyone who can speak the lingua franca of AI, (i.e. write programming code). Probabilistic Programing for Advanced Machine Learning highlights that the number of researchers and experts in ML development are far less than the potential applications, there is fundamentally not enough skilled workers to pursue all avenues of development. This leads into the general nature of military AI development and discourse that is available at the moment.

Significant future trends are analyzed, discussed and critiques for potential advantages, impacts or ramifications, at the United States War College and institutions like CGSC and SAMS. The general nature of these documents is speculative, as we have seen very little demonstrated AI in the military to date. The most visible and publicized have been drone developments[40] and in particular swarming technology, but once again this represents but a small portion of the fields of research available to military organizations about AI implementation.

The military debate on AI as a field is dominated by the idea of autonomous systems and the associated ethical dilemmas[41] posed by the potential transitions to machine-led warfare. It is important to note that no ethical debate is limited to the

[40] Department of Defence, *Unmanned Systems Integrated Roadmap FY 2013-2033* (Washington, DC: Government Printing Office, 2013).

[41] Department of Defence, Department of Defense Directive 3000.09, *Autonomy in Weapons Systems* (Washington, DC: Government Printing Office, 2012).

implementation of policy, and does not prevent the development of technology with ethically questionable behavior. Regardless of the personal feelings about AI, its development is ongoing and widespread. The final parts of this chapter are short discussions of concepts that help the reader understand in more detail the developmental barriers to AI and associated technologies.

Complexity

We touched earlier on the issue of complexity, and I want to revisit here to provide more context in the thinking and application for AI in both the civil and military environment, and in some way, demonstrate why AI has been slow to progress and potentially disappointed researchers who were developing programs like Future Combat Systems.

Complexity in the context of AI can have many meanings, the first and primary has to do with the class of problems that can be solved in polynomial time, of which another way of saying this is those problems that have a computational solution. These are known as P. Those that cannot be solved called NP. The conventional wisdom, however not proven is that $P \neq NP$ (i.e. there is a class of problems that can only be approximated and not solved). The hardest of these problems are called NP–complete.

The second problem with complexity comes from the observations of geometric progression, in particular, non-convergent geometric progression. Much of the ideas in AI deal with multiple interrelated variables that can assume a staggering number of potential states. The classic example of the power of geometric progression is the parable of the invention of chess, in which the inventor asks for a reward of grains of wheat, with one grain in the first square and doubling per square of the chess board. Which sounds

reasonable at first, but is, in fact, equal to 2 to the power of 64 minus one grain of wheat, a number much larger than is intuitive and significantly more than the world production of wheat. Now if one was to take this idea of complexity, and apply it to computational power available and the modeling of neural net connection, it can be seen that even with the staggering increase in computing power, it does not match the complex representation of a relatively simple neural net. If the computational power does prove to be a barrier to current methods to develop General AI, it does not mean that some other model of learning and intelligence, requiring far simpler implementation does not exist, and this possibility is explored about a phenomenon known as Black Swan events.

Black Swan Event

The Etymology of the term Black Swan event comes from the widely-circulated tale that the modern world "knew" that there were only white swans in the world. This established fact was disproved with the discovery of black swans in Australia, in essence, a rare occurrence disproves an established "truth." This leads to a proposition on the usefulness of logical statements that it is easier to use data to reject statements than to confirm the hypothesis.[42]

The black swan event in AI is the idea of a technological singularity, an event where a General AI is created which rapidly becomes more intelligent than the human race and surpasses our understanding of the known world. Just what occurs after the singularity is unknown, but as we can observe that no general AI exists today, we cannot

[42] Nassim Nicholas Taleb, *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets* (New York: Random House, 2005).

exclude the possibility of one being created, as we can clearly observe in ourselves the notion of intelligence and therefore the potential to replicate it.

Robotics

Robotics is hard to define, and continuously evolving. Bernard Roth, a long-time researcher in the field of robotics, provides a relative and conditional definition of Robotics. “the definition of a robot has to do with which activities are associated with people and which are associated with machines. . . . If a machine suddenly becomes able to do something associated with a human, it can be upgraded in classification as a robot, after a while people get used to the activity being done by machines and the devices get downgraded from ‘robot’ to ‘machine.’”[43]

Robotics are physical agents that perform tasks by manipulating the physical world.[44]They are classified into three categories, manipulators such as factory robotic arms, mobile such as unmanned vehicles and the third being mobile manipulators that are a combination of both.

Robotics is of interest to AI because it provides a vehicle for autonomous physical agents. Robotics does not require an AI to function, in fact, the majority of implemented Robots in the modern world use Control Theory and hard-coded programs to execute their function. This observation is important as it is possible to have automation without intelligence, the functionality that a military’s desire with fully autonomous weapons

[43] Bernard Roth, Foreword to Bruno Siciliano and Oussama Khatib, eds., *Springer Handbook of Robotics* (Berlin: Springer-Verlag, 2008), viii.

[44] Norvig and Russell, 971.

systems can be solved with classic programming implementation. AI implantation in robots offers a pathway to developing better, more efficient systems, and for research purposes is one of the approaches to AI experimentation.

Control Theory

Cybernetics, more often referred to as control theory is a multi-disciplinary field of science that "studies communication and control in animals and machines." In the 21st century, the meaning of cybernetics has evolved to mean "the control of any system using technology." It is this broader definition which is of relevance to military studies.

Control theory can bridge the gap between an AI and the physical world, but it also offers an approach to automation that is not reliant on intelligence per se. The father of control theory Norbert Weiner developed linear predictors to automate (guide) the anti-aircraft guns during World War Two.[45]

Wiener's theories relate to dynamic systems with inputs that are in turn modified by a feedback loop. The mathematical basis for control system engineering used extensively in modern industry; the field has implications for physiology, electronics, climate modeling, machine design, ecosystems, navigation, neural networks, predator–prey interaction, gene expression, and production theory.

In control theory and AI, a mixed implementation may result in far more capable machines than currently possible.

[45] Weiner.

Artificial Intelligence, Control Theory, and Robotics

If one thinks of AI as the mind, and Cybernetics as the senses, and the Robot a physical body, when the three fields are combined the resulting output is a simulacrum of the human condition. Cybernetics bridges the sensory and action gap for an intelligent entity such that it can perceive, adapt and manipulate its physical environment. The conjoining of intelligence, with body and senses, is the stuff of science fiction, and in some cases horror movies, but it is a very real and logical progression for technology to be taking in the 21st century.

A Common Theme–Biomimicry

In all three fields of research, the common theme has been one of biomimicry, the replacement or mimicry of human functionality, whether cognition or interaction. There is a prevailing position in research that the attempt to replicate human capability through technology is limiting the development of many fields. The example that is demonstrated is the pursuit of heavy than air flight; initial designs included flapping wings that mimic a bird in flight. The solution we utilize today is vastly different, involving the utilization of an engine developing thrust and an airfoil that generates lift. Likewise, the wheel has no functional resemblance to a leg for the purpose of locomotion. Researchers such as John Jordan postulate that true advances in Artificial Intelligence will no more resemble the human brains as the airplane resembles a bird.[46]

[46] John Jordon, *Robots–The MIT Press Essential Knowledge Series* (Cambridge, MA: MIT Press, 2016), 21.

The tendency to anthropomorphize AI, with terms like “learning,” “intelligence,” “agent,” “behavior,” shapes the way we think of AI in human terms, when there could be nothing further from the truth. It leads to misguided assumptions and limitations on the advancement and implementation of AI.

CHAPTER 3

RESEARCH METHOD

Research Methodology

The Purpose of the research is to determine the extent to which AI as an emerging technology is developing as a Military Revolution or an RMA.

The questions that must be answered to satisfy the thesis questions are:

Primary (1)-Will Artificial Intelligence, cause a revolution in military affairs (RMA) or a military revolution (MR).

Secondary (2A)–What are the characteristics of an MR.

Secondary (2B)–What are the characteristics of an RMA.

Secondary (2C)–How does AI compare to the answers for 2A and 2B.

To answer these questions in reasonable time and completeness are given the general nature of the underlying theories, I have chosen to conduct comparative qualitative research in completing this thesis. The reason for this choice is due to the general nature of the research question as stated, and due to the somewhat unquantifiable nature of emerging technology.

The basis for choosing this method is taken from (Qualitative Inquiry and Research Design)[47] and is aimed at understanding Artificial Intelligence within the natural environment of the concept of Military Revolution and RMA.

[47] John W. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches,* 3rd ed. (Thousand Oaks, CA: SAGE, 2013).

The method will use the currently published theories of Military Revolution and Revolutions in Military Affairs and then refine the key characteristics that have been identified by previous researchers, to provide a framework for identifying how emergent technology can have the potential to cause either an MR and RMA.

The key characteristics are then used to assessed by case studies of Artificial Intelligence through qualitative analysis of books, journals, and articles. Mapping back specific examples across multiple domains to determine to what extent Artificial Intelligence compares to previous RMA or MR.

The results of the research while broadly applicable to technology can be further refined by the specific nature of publications, volume, and level of research to determine if one or more nations are leading the development of Artificial Intelligence.

The research will be divided into the following phases and follows the logical flow in figure 2.

Flowchart of Research Logic

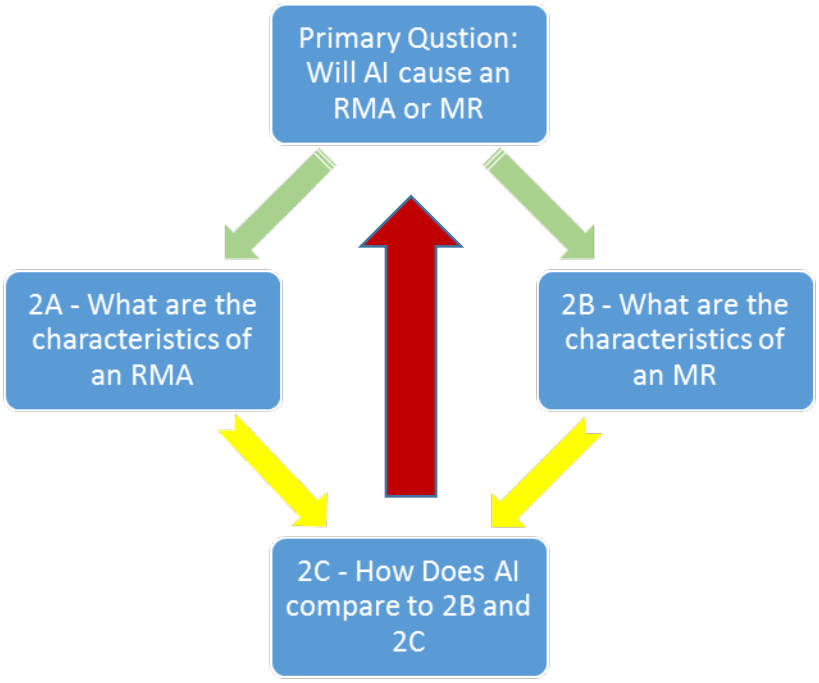

Figure 2. Logic Flow for Analysis

Source: Created by the author.

Phase one will be the literary review contained in chapter 2 and development of the framework for comparing an emergent technology to an MR and RMA; this is achieved by using existing analysis of RMA and MR frameworks provide by established theory. This phase will conclude with the method to develop the framework and how it will be applied in chapter 3.

Phase two will consist of the analysis of MR and RMA theory to provide the characteristics, answering research questions 2A and 2B. AI will then be compared to the framework using books, journals, and articles to demonstrate or disprove application

through case studies analysis of AI in military domains of Land, Sea, Air, Space, and Cyber and more general application within the wider scope of civil technology development. In this way question, 2C will be answered, and the comparison of 2C to the distinctions between RMA and MR will provide the answer to the Primary Research Question.

CHAPTER 4

ANALYSIS

The primary research question is; Will Artificial Intelligence cause a revolution in military affairs (RMA) or a military revolution (MR)?

The analysis will answer the primary and secondary research questions in a systemic and logical way, demonstrating the relationships between MR and RMA theory, and AI.

As described in chapter 3 the logical flow requires that the secondary research questions be answered to provide insight into the primary research question. As described in chapter 3 case studies of MRs and RMAs will be used to identify key characteristics for comparison to Artificial Intelligence.

Case Studies of Military Revolutions and Revolutions in Military Affairs

I have concentrated on three MRs and several RMAs that can be compared and contrasted to build some level of understanding of characteristics, features, and consequences as a result of MR and RMAs. I have chosen the Industrial, French and Nuclear Revolutions to analyze MR as they provide a contrast between technology, society and in the case of Nuclear Revolution a less defined and distinguishable MR which helps to highlight the problems of categorization.

In the RMAs, I have attempted to demonstrate what makes them different from MR and how they have more chronological and action—reaction based iterations. They more clearly demonstrate a military concept and in the case of Napoleonic Warfare, highlight when an RMA becomes so dynamic that it masquerades as an MR.

The Modern State and Military Institutions

I have included this period, only to highlight that it is general the start point for discussion on MR and RMAs. The style of warfare in 17th century Europe changed so fundamentally that many scholars regard it as a Military Revolution. The changes wrought influenced tactics, military organization[48] and the societal perception of what it meant to be a soldier. The change occurred over a significant period, and some historians would contend that this was evolution not revolution,[49] disregarding the timeframe the result of either process was the genesis for the modern army that has maintained a dominant place in nation states to this day. Technology is one factor in the changes wrought on military organizations, the influence of the fusil or flintlock over matchlock muskets would eventual change the infantry formations and make medieval weapons like the pike largely redundant. More so cultural reform in the military is argued to have been the driving influence that allowed the European nations to develop a distinct advantage in the waging of warfare. Development of the state commissioned army, as opposed to aggregate contract armies, was to prove a significant shift in the development of warfare.[50] These commission units while taking longer to raise, were considered to be easier to control, more loyal and more proficient.[51]

[48] Macgregor and Murray, 36.

[49] Ibid., 35.

[50] Ibid., 52.

[51] Ibid., 53.

Of the discussed Military Revolutions, this is probably the least profound, yet it provides the foundation for the modern concepts of militaries and military organizations. It is the cornerstone from which the following Revolutions build new systems for warfare.

French Revolution

Before the French Revolution and the revolutionary wars that followed, the monarchical or narrow oligarchies that ruled most nations were constrained in the economic means and mass to conduct decisive military campaigns.[52] The societal change from the regime to citizen removed the barriers to the limited warfare of old. The French army swelled in size by an order of magnitude; nationalism freed the soldier to forage without fear of desertion and offered the possibility of operational maneuver. Changes in tactics soon followed with *l'order mixe* allowing swift movement and re-order for fighting. The response from adversaries was mixed, with political resistance hampering any real counter until Prussian reforms post Jena–Auerstadt in 1806. However, in essence, those reforms mirrored the revolutionary change of universal military service, and independently, a thinking officer corps or the modern military staff to counter the individual brilliance of Napoleon. Even with the defeat of Napoleon the character and conduct of warfare had been changed.

Industrial Revolution

The industrial revolution is founded in the transition from hand production to machine production that occurred (is continuing to occur) since the 1770s in Britain and

[52] Ibid., 59.

then spreading to the rest of the world.[53] The industrial revolution is perhaps the most profound change in modern history, and it is born out of the replacement of human and animal power with mechanical sources of power, varying from fossil fuel, water, the wind and more recently nuclear power.[54] It was so profound that it redefined the way people worked, where they lived and the economic surplus that corresponded with a greater capacity for support and lifestyle.[55] The revolution is born out of technology, followed by organizational forms and extensive adoption.[56] The effect on the military was significant, in the United States, which industrialized first in textiles and transportation then during the civil war industrialized its military industry.[57] The industrial revolution brought new tools for the conduct of warfare, railroads extended operational reach, the telegraph allowed communication over great distance, but perhaps most important, the revolution generated wealth that could be harnessed to raise and sustain armies, but also drive innovation and change.[58] The conduct of militaries and the gains in lethality and massed warfare that ushered out of the industrial revolution foreshadowed possibility and scale of the Great War.

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[53] Peter N. Sterns, *The Industrial Revolution in World History*, 4th ed. (Boulder, CO: Westview Press, 2013), 1.

[54] Ibid.

[55] Ibid.

[56] Ibid., 13.

[57] Ibid.

[58] Williamson Murray and Allan Millett, eds., *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), 1.

World War One

Scholars like Williamson Murray, MacGregor Knox, include in their framework of Military Revolutions the culmination of events from the French and Industrial Revolution, associated RMAs, and the grand conflagration of ideas and approaches to warfare that fused in the crucible of World War One.

World War One occurred on a scale that was another order of magnitude greater than the Napoleonic and US Civil Wars. The vast number of mobilized nations fighting within the European theater and abroad was staggering.

World War One represents the combined power of Industrialization and French Revolutionary ideas fused into a greater entity. Within this context rapid emerging technology is changing the nature of offensive and defensive operations, the pace at which innovation occurs is faster than the understanding to implement it. The cost of not fully understanding the effect of emerging RMAs within the greater context of the world war one MR is paid in a steep sacrifice of people and resources. The period after World War One and before World War Two is explored as an RMA as the Interwar Period. This period is heavy studied as an example of innovation and adaptation, which form two pillars of the RMA.

Nuclear Revolution

During the conduct of World War Two, both axis and allied research were endeavoring to develop the first atomic weapons. The staggering resource and financial investment that went into the Manhattan project demonstrates the awareness of how profound this technology based innovation could be to the conduct of warfare and the outcome of the War in Europe and the Pacific.

The two atomic bombs dropped on Japan in 1945 demonstrated the fundamental change that the use of such weapons could bring to the battlefield. The fact that Russia could replicate the technology and explode its own nuclear weapon in 1949 sent a shockwave through the west and ushered in an arms race that came with a large economic cost to both the United States and the USSR.

The threat of nuclear weapons changed the perceptions of civilians as well, but also ushered in an age fueled by the hope of a nuclear future, a technology born in a war created the platform for some of the greatest accomplishments of the modern era.

While the prospect of tactical nuclear weapons could offset (1st offset) a numerically superior conventional force, the historical reality of nuclear revolution is twofold. The prospect of mutual destruction resulted in a Cold War between nuclear powers, and for the non-nuclear states, any military action against a nuclear power must always be conducted with the prospect of a nuclear retaliation, no matter how limited, no non-nuclear nations can challenge the established nuclear powers through conventional means.[59]

Information Revolution

Computers, Communication, and Social Media are increasingly considered to be the latest social-military revolution.[60] The significance for the modern military thinker outlined by Williamson Murray is that internal RMAs drove the contemporary period

[59] Robert Jervis, *The Meaning of Nuclear Revolution* (London: Cornell University Press, 1989).

[60] Murray.

from 1914 to 1990. The military-social revolution that is occurring now marks a transition back to innovation that is beyond the control of the military.[61]

The sixth revolution is shaped by the looming black swan(s) some potential events that could theoretical upset the geostrategic environment. Economic collapse being the most likely.

To survive the 6th military social revolution, the United States needs to remain flexible, and adaptable to deal with the uncertain conditions the battlefield may present, to include the possibility of being denied the use of the precision, information-based systems that were developed in the 1990s RMA.[62]

Summary of the Characteristics of a Military Revolution

If we accept the validity of the historical Military Revolutions, we can determine how they influenced military organizations and drew out some observations as indicators of potential dramatic and widespread change.

The Military Revolution begins with a theory or concept and over time upsets the established military-social order. While technology is an obvious determinant of change, it is one of many that can result in MR. The French Revolution is a demonstration of the power of political and societal change that allowed one nation to wage warfare in a new and profound way. Of the most recent MR, the industrial and nuclear revolutions resulted in technological change that affected the established social order. The industrial revolution was widespread, whereas the nuclear revolution has predominantly affected

[61] Ibid., 62.

[62] Ibid., 176.

the nuclear powers and their local geographic context, specifically the effect of the nuclear revolution was more profound in the United States, Europe, and Asia. The first observation is that Military Revolution can result because of new theories and-or practice in either, politics, society, economics and technology.

I will contend here that the Nuclear and Industrial Revolutions were not singular technology based, but rather the result of rapid technology changes as a result of scientific advancement. The Nuclear and Industrial revolutions represent the fruition of ideas that affected multiple fields of science and engineering as well as created many new technological advancements, not all of them which would affect the military. The industrial revolution resulted from new ideas in manufacturing, organizations, and power sources, while the nuclear revolution was born out of theories on nuclear physics. The observation is that new fields of research, with associated scientific advancement, provide multiple technological avenues that can drive Military Revolution. In this way, the distinction between "technology" and "field" will provide one means of distinguishing between MR and RMA.

A Military Revolution in some way must make the established forms or warfare redundant, either through the development of new systems for warfare or rendering the previous systems obsolete.

When a Military Revolution is sweeping through society, the ability to recognize, analyze its meaning and then implement change is paramount to having a decisive effect. The change in doctrine, tactics, operations and strategy must be developed, and communicated in a way that the military understands how to implement the new modes of warfare. Not all nations start out on the same footing, to make use of the industrial

revolution in warfare, a nation needed to be industrialized. As a result, any political or social barrier to adoption may lead to severe disadvantage in utilizing the benefits of a new revolution.

A Military Revolution cannot occur without organizational change and adoption because the change is external, the choice to embrace or resist change is institutional. While adoption may become inevitable, failure to recognize it early will ultimately lead to a military disadvantage. Therefore, for a Military Revolution to be to be realized and organizations must actively pursue and implement the options and opportunity presented by the latent Military Revolution. This observation provides the link between MR and RMA. Military Revolutions are propagated by the implementation of RMAs that are intern influenced by the geo-strategic realities of the nation pursuing the RMA.

Adoption may be the most difficult of all aspects due to the foresight required to understand the broader implications that it will have on the military, society, politics, and economics of the world.

The final observation made about MR is that the effect seems to be cumulative, in that the ability to adapt or react to an MR is dependent on the nation's previous MR. It is difficult to transition to Industrialized warfare without having the supporting cultural revolution to support it, likewise, without industrialization, it is difficult to implement the Information Revolution. The importance of this observation is that the most likely location for successful implementation of a new MR is in those nations that have successfully harnessed the previous MR.

Examples of Proposed Revolutions in Military Affairs

The following are but some of the most researched and analyzed Revolutions in Military Affairs, they draw heavily on the work of Andrew Krepinevich who summaries them eloquently in his article "Calvary to the computer; the pattern of military revolution."[63] Krepinevich makes no distinction between MR and RMA; the following revolutions demonstrate the chronology of interplay of various RMA and MR as they applied in the military domain. Where duplication occurs, such as Napoleonic Warfare born out of the French Revolution, it is my view that Krepinevich focused on the military ramification rather than explore the broader societal impact.

Infantry Revolution (1337)

The Infantry Revolution, saw infantry displace the dominant role of heavy cavalry on the battlefield. During the period leading up to this military revolution, infantry consisting of tight formations of pikeman and crossbowmen were predominantly used to protect the cavalry as it formed up to charge. During the first half of the 14th century, however, the infantry—in the form of Swiss pikemen and English archers—emerged as a combat arm fully capable of winning battles in their own right making the employment of more expensive Calvary increasingly rare.[64]

Technological innovation in the form of the six-foot yew longbow, which gave English archers a much-enhanced ability to penetrate the armor of cavalrymen as well as

[63] Krepenvich.

[64] Ibid.

both missile and range superiority over their adversaries[65]coupled with the English developed a tactical system based on integrating archers with dismounted men-at-arms provided a decisive advantage. Thus, the Infantry Revolution combined technical and tactical innovation, and demonstrated through the French failure to adjust in a timely manner, the asymmetric advantage of an RMA.

Revolution of Sail and Shot (Naval 1500s)

The Naval Revolution in the 1500s demonstrates a non-land domain revolution in military affairs. It is a good demonstration of the effect of a previous RMA effecting a new development. The revolution is founded on the merging of two developing technology, large sailing ships which were large enough to mount and utilize artillery pieces.[66]

The lighter galley, oar-propelled had been the ship of choice among European nations, the larger and more powerful sailing ships, won decisive battles in the 1500s. This RMA also demonstrates the interplay of advantage and adaptation. Nations were quick to introduce the same technology to maintain some balance. This is a recurring theme of RMAs; the advantage is relatively short lived, when technology or concepts prove themselves in conflict, most nations with a similar industrial or technical base will attempt to adopt some or all of the RMA.

[65] Ibid.

[66] Ibid.

Gunpowder Revolution (1550s)

Muskets capable of piercing plate armor at a range of one hundred meters were introduced in the 1550s. The English abandoned longbows in the 1560s for firearms. Finally, in the 1590s the Dutch "solved" the problem of muskets' slow rate of fire through a tactical innovation that saw them reorganize in extended lines which maximized forward firepower. These linear tactics allowed for a nearly continuous stream of fire as one rank fired while the others retired to reload. Muskets were also attractive to adopt because they required little training in comparison to the years necessary to develop a competent archer (although linear tactics did require a considerable drill to ensure coherence and rate of fire).[67]

Linear tactics were refined under the Prussian military system of Frederick the Great, who achieved significant improvements in the rate of fire of soldiers, as well as major improvements in supply[68]. These would be nullified more advanced systems and improvements under Napoleonic Warfare. In this sense, an RMA will be countered by a superior system of battle combined with relatively minor technological advances, but one which will occur within the context of a social-military revolution.

Napoleonic Warfare

The revolutionary nature of Napoleonic Warfare most clearly represents a combination of RMAs that in concert, many historians like Williamson Murray have

[67] Krepenvich, 5.

[68] Ibid.

described as a Military Revolution in its own right.[69] We can, however, be clear that the Napoleonic Warfare owes its superiority to developments in Industrialization and most importantly for Napoleon the French Revolution, which redefined what it meant to be a citizen of a nation. During this period, thanks to the emerging Industrial Revolution, the French standardized their artillery calibers, carriages and equipment, and fabricated interchangeable parts. Other improvements in industrial processes allowed the French to reduce the weight of their cannon by 50 percent, thereby increasing their mobility while decreasing transport and manpower requirements dramatically.[70]

The introduction of the *levee en masse* following the French Revolution helped to bring about an order of magnitude change in the size of field armies. Citizens proved much more willing to defend and fight for the nation than the crown. Consequently, France's revolutionary armies could endure increased hardship, and attack almost regardless of the cost in men (since they could call upon the total population resources of the nation). In battle, the individual could be more effectively relied upon; skirmishers and individually aimed fire could be integrated to great effect into the volleys of artillery and musketry. Furthermore, armies became so large that they could now surround and isolate fortifications while retaining sufficient manpower to continue their advance and conduct field operations, thus largely negating the effects of siege warfare.[71]

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[69] Macgregor and Murray.

[70] Krepenvich, 5.

[71] Ibid.

The latter part of the 18th century also witnessed the creation of a new self-sufficient military organization—the division—and specialized infantry and cavalry units for skirmishing and reconnaissance, screens and raids. A growing network of roads in Europe meant it was possible for an army to march in independent columns and yet concentrate quickly for battle.[72]

Napoleon's genius was to integrate the advances in technology, military systems, and military organizations (including his staff system) to realize a dramatic leap in military effectiveness over the military formations that existed only a short time before him. Indeed, it took the other major military organizations of Europe at least a decade before they were able to compete effectively with the Grande Armee that Napoleon had fashioned.[73] The Napoleonic Warfare revolution most clearly demonstrates the role in which leadership, doctrine and organizational change can utilize technology to generate an RMA.

Land Warfare Revolution

Between the Napoleonic Wars and the American Civil War, the introduction of railroads and telegraphs, and the widespread rifling of muskets and artillery again dramatically transformed the character of warfare, the result was the Land Warfare Revolution.[74] The land warfare revolution provides an example where multiple RMAs are combined to generate a shift in warfare that is greater than the sum of its parts.

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[72] Ibid.

[73] Ibid.

[74] Ibid.

Both the Union and the Confederate forces used two new technological innovations to change the context in which the war could be waged. Rail networks greatly enhanced strategic mobility and sustainment, the pattern of conflicts can be seen to flow and follow the rail networks for the majority of the war (particularly in the eastern theater) . The single exception is Sherman's decision to abandon his supply lines and forage for supply, which was the result of an ideological shift in what was acceptable in conducting the war. Early dispatches on both sides of the war, demonstrated a reluctance to disadvantage non-combatants.[75] With Armies operating over longer distances the use of telegraph to coordinate maneuver, and linked more directly the political and military leadership to the commanders in the field. Lee was perhaps the best example of utilizing the telegraph first to communicate orders to dispersed armies, but also to mass his armies at a point of decision rapidly.

Improvements in muskets, particularly the rifled weapons and later repeating rifles dramatically increased the killing range and rate of fire of infantry. As the US Civil war progresses the combination of increased lethality and old doctrine results in greater losses.

Adaptation to this new regime to warfare would be slow, but the fighting towards the end of the civil war demonstrated the precursor to trench warfare defenses[76] that

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[75] Robert E. Lee and Jefferson Davis, *Lee's Dispatches: Unpublished Letters of General Robert E. Lee, C.S.A. to Jefferson Davis and the War Department of the Confederate States of America, 1862-65, from the Private Collection of Wymberley Jones de Renne, of Wormsloe, Georgia* (Baton Rouge: Louisiana State University Press, 1994).

[76] James M. McPherson, *Battle Cry of Freedom: The Civil War Era* (New York: Oxford University Press, 1998).

would see large-scale employment in the first world war discussed in MR theory. The period between the great wars was one of significant technology innovation and adaptation and is known as the interwar period.

Interwar Revolution–Mechanization

As World War I progressed, the land forces of both the Allied and the Central Powers found themselves employing new military systems based on dramatic advances in the fields of mechanization and radio. Following the war, improvements in engines, aircraft design, and the exploitation of radio and radar made possible the tactic of blitzkrieg, innovations in carrier aviation, modern amphibious warfare, and strategic aerial bombardment concepts for war; some would consider each of these an RMA. From these RMAs entirely new kinds of military formations appeared, such as the panzer division, the carrier battlegroup, and the long-range bomber force. After a brief twenty years, the character of conflict had changed dramatically, and those nations—like the British and the French—who failed to adapt suffered grievously.[77]

The interwar period demonstrates the power of multiple RMAs across multiple domains, while Krepinevich's language describes this period of change as closer to an MR, it is mostly driven by doctrinal and organizational innovation, with the technology being iteratively better versions of previous developments. Whether a critical mass of RMAs should be considered an MR instead is an ongoing debate among commentators on the history of military revolution.

[77] Krepenvich.

The United States' Revolutions in Military Affairs of the 1990s

The United States Military had been undergoing significant force structure and technology-based innovation in the period after Vietnam and before the Gulf War in 1991. While the ideas of General Creighton Abrams and the big five platform acquisitions which still form the basis of the United States Army today have proven in hindsight to be dominant in land operations for a significant period. The excitement was really about a transformation of the Air Force, one in which it was believed that "strategic" effect could be delivered.[78]

During this period, it was recognized that IT was having an effect on wider economic and social structures and that there was a certain inevitability for military change as a result of the information revolution, the development of stealth, precision guidance and precision munitions in combination with new ideas about special forces, fronts and secure areas, fueled by an information overmatch, which would reduce the "fog of war" formed the basis for a transformation in the way the United States would wage war.[79]

The results of the first Gulf War lead credence to the dominance of the United States Military system, the destruction of Iraq's Military within 100 hours is hard to argue, in a conventional fight the United States, superior technology, training, structure, and organizations had proved its worth.

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[78] Keith L. Shimko, *The Iraq Wars and America's Military Revolution* (Cambridge: Cambridge University Press, 2010), 12.

[79] Ibid.

Despite having and still retaining conventional military dominance, the RMA was not structured to fight non-conventional warfare, the insurgencies in Afghanistan and Iraq speak more about adversaries' adaptation than failings of the RMA. What perhaps is most shocking to the United States military is the pace and success in which potential and named rivals have developed and implemented their own RMAs to counter the United States' information dominance.

Summary of the Characteristics of a Revolution in Military Affairs

The first distinction that is clearly made and accepted by most commentators on MR and RMA is that the drive and the cause of RMAs are the military establishments. There is the clear interplay between MR and RMAs, but the distinction allows an observer to track the development of RMAs independently of a concurrent or incipient MR. This is important, in that it makes it clear that RMAs can happen before, during and after MRs and can benefit or be neutralized by the concurrent output of an MR.

The mechanism and indeed the magnitude of the effect caused by an RMA can be thought of as a chemical reaction, requiring ingredients and accelerated by a catalyst. New ingredients coupled with powerful catalyst produce the most dramatic and decisive RMAs.

Technology is most often the driver of an RMA and while some consider it merely a catalyst.[80] I feel if warrants sufficient weight as both ingredient and catalyst. Some innovations are limited to domain specific advancement, while others can be

[80] Macgregor and Murray.

utilized in a variety of domains. Simple examples would be rifled guns and artillery, improved range and accuracy of these weapons were able to be implemented in vehicles, aircraft, naval craft, fortifications. The variety of systems for potential implementation determines the second ingredient of the RMA, the greater the number of affected systems, the increased application and magnitude of the effect.

Taking these two ingredients (Technology) and (Scope) there are two moderators which drive or inhibits RMAs, and these are found in either implementation and organizational adaptation. Implementation can be considered to be the innovative application of doctrines, techniques, and procedures that fully realize the emergent capability of the RMA, The German concept of blitzkrieg combined the output of mechanization and firepower to form a new concept of combined arms maneuver. The technical systems were available to the French and British forces during the same period. However, it was the Germans that caught the Allied forces unprepared for a novel approach to warfare.

The final catalyst, or in many cases could be considered an inhibiting agent is an organizational adoption. The choice to implement change whether driven by military leadership, political or social policy, geostrategic context, cannot be ignored in generating an RMAs. Without the organizational will to adapt there will be none of the innovation and development required to produce an RMA. An example of the profound nature of organizational drive is the United States Big Five which were proposed by General Abrams and to this day forms the foundation of United States Conventional warfare dominance.

In summary, the product of the RMA reaction is the sum of the following:

New Technology + Systems X Innovation X Adoption.

The greater the output the closer an RMA will appear to be an MR.

Distinguishing Revolutions in Military Affairs and Military Revolutions

While not exhaustive and open for debate, the combined work of theorist outlined in provides the basis for understanding the following examples of Military Revolution and Revolutions in Military Affairs.

Military Revolutions and RMAs share many similar characteristics; however, they are distinguished primarily by two factors. The first general factor that differs an MR from and RMA is the magnitude of the impact on not only warfare but also society. The second factor is the genesis for change, and are distinguished by internal revolution or external societal change. The Military Revolutions are characterized by abrupt and sudden changes in the fabric of society, laws, wealth and social norms, whereas an RMA is a process driven in part by the military itself, its genesis is internal as opposed to external.

Military Revolutions and RMAs are not mutually exclusive; they can be occurring simultaneously and for differing reasons.

Discrete technical innovations can be general contained to the RMA while as a sweeping technological idea, new fields or research or understanding can provide the nucleus for Military Revolution. Are there innovative concepts for the implementation of new technology? Moreover, more importantly, do they make previous evolutions of RMA redundant, and will the technology only affect one domain and technology or does

it make multiple systems redundant and fundamentally shift the balance of military capability.

What organizational drives or barriers are fostering the implementation of the potential RMA or harnessing the innovations that are manifesting as a change in the latent MR.

This thesis will now look at Artificial Intelligence within these subjective lenses.

Is Artificial Intelligence a "Technology" or "Field"

As a concept, AI is not "new," it is however constantly changing with the theories and technology that underpin its implementation. AI has at times been maligned by offering bold visions of the future and often failing to deliver on them, concurrently theories on how to pursue, implement and develop AI have changed over time.

Alan Turing is considered the father of Artificial Intelligence, (Turing Test, computing power, the imitation game) and the genesis for a modern popular understanding of the AI concept. For some researchers, the goal of AI is to pass the Leobner version of the Turing Test, yet for many other researchers, the goal of human imitation is seen as restrictive and fundamentally limiting for the development AI.

Blay Whitney[81] described the current approach to developing AI in military terms as "assaulting a wide front with multiple small forces hoping for a breakthrough, more often than not only advancing the front a few yards at a time."

In this sense, AI is developing new and emerging tools across multiple fields with advances occurring on a daily basis. Some provide merely better algorithms for solving

[81] Whitby.

problems while others are fundamentally changing the field for which they apply. This interrelated discovery is most evident in fields with significant overlap. Cognitive Science is benefiting from the application of AI, in neural networks, but also in understanding concepts like graceful degradation. Simulated neural networks allow scientist to explore the workings of the human mind and formulate theories about human cognition.

It must be noted that the majority of current research is contained within the scope of narrow AI. Finding solutions to complex but clear problems is of significant financial benefit to the real world. An example of such a requirement is the traveling salesman problem. The traveling salesman problems asks, given a list of cities and distances between them, what is the shortest route that visits each city once and once only and returns to the origin?[82]

The traveling salesman problem is thought to be an NP-hard problem, which translates to a problem that is not solvable through computation, it, however, can be approximated by algorithms. Solutions to the traveling salesman are used from logistics distribution to navigation software, automated drill bit paths and stocking machines,[83] elegant or efficient solutions offer competitive advantages especially when one considers the scale of the problem when you start thinking about Amazon logistics distribution. The algorithm that controls, the selection, grouping, shipping and delivery of Amazon products on a daily basis is an advance algorithm a form of narrow AI.

[82] Norvig and Russell, 74.

[83] Ibid.

This example demonstrates the general utility of an AI approach to solving problems. Each implementation fundamentally generates a new or improved solution. In this way, the field of AI is incrementally improving the outputs of various real world problems.

Thinking of AI as a field of research, rather than a singular technology opens the doors to innovation and implementation. Where ever there is a problem, task or output and a desire to improve efficiency in decision making, AI offers an avenue for development.

The conclusion that is made here is that Artificial Intelligence has more similarity to the scope and change that was the result of industrialization than it does to the development of the tank. It is clear that AI is influencing and driving the development of new technology.

Chapter 2 demonstrated that the civilian world, in particular, corporations is driving development and implementation in AI. It is being woven into the fabric of technology within our society. Whether this process is driving political or societal change is yet to be seen, but developments in wealth generation may be laying the seeds for significant change.

Beyond the obvious face of AI, the Google and Amazons of the world, the uptake of AI in other sectors has been strong. Many people may not realize that the majority of hedge funds and large venture capitalists are using or pursuing AI and algorithms to predict or direct financial trades.

It is clear that the effect of AI is far wider than just military application, it has demonstrated a range of new technology, and innovation, but we must now consider how AI can fundamentally affect military systems and the character of warfare.

Can Narrow AI make the Established Forms of Warfare Redundant?

So, what does AI do for the established form of warfare? The modern conventional armies of nations today are fairly similar. We have established doctrine and understanding in the domains of Land, Air, and Sea. While minor improvements and advantages have been gained in niche capabilities, stealth, A2AD, tanks systems, naval design, precision weapons to name a few, the fundamental platforms have largely remained unchanged since World War Two.

In these traditional domains, automation offers the possibility of reducing the density of human combatants. By this, I refer to the ability to remove the human from the system and therefore reduce the risk to the military of human casualties. It does very little for the civilian who may find themselves in a war zone, but de-risks warfare for the autonomous army.

The outcome of automated vs. human military systems is an area of research that should be explored through simulation and experiment. However, besides the relative cost to human life between combatants, there has been no shift in the way a nation conducts warfare, it would be an assumption requiring proof that the balance of military power would remain with the countries that have a demonstrated industrial output to sustained large scale conflict, automation through narrow AI may not be enough to shift any region power balance.

This assumption may change if the capability of automated systems is an order of magnitude more efficient that existing human systems. In this scenario, economies of scale may sufficiently change the nature of warfare, but it is as yet an un-demonstrated capability.

The complexity of multi-domain warfare and the requirement to generate pockets of relative superiority may be the result of current technological parity, or counter measures. In this environment, the role of AI may be more suited to the development of systems that can plan, synchronize and execute faster than the human staff.

In the sixth generation of MR discussed by Williams Murray, we have established a new domain for warfare. The cyber domain is built from the ground up on electronics, connections and computing systems. Algorithms and AI "rule" within this environment. While initial forays have relied on human technicians to compete within this realm, the reality is that talented groups of programmers generate and exploit technology-based solutions, utilizing automated systems, and algorithms to exploit and conduct operations within the domain.

Artificial Intelligence, in this context, is not making the established forms of warfare redundant, just least costly, as such it has not exhibited the change necessary to be considered revolutionary.

Does Artificial Intelligence have Application over a Wide Variety of Systems?

Artificial Intelligence undeniably has application in any system or domain that can be automated, or requires a decision to be made, or indeed just optimized. AI is

restricted only by imagination for implementation. What we do not yet see in AI research is totally new systems or ideas for warfare as a result of AI research.

Artificial Intelligence has not given us a “new weapon” for the conduct of warfare. The evolution of an AI as a weapon remains the realm of science fiction for now. The reason for this is due to the as of yet development of general AI. As we know from the discussion of current technology, developments are strongly favored in the domain of Narrow AI with General AI remaining a theoretical possibility. The implication for which includes intelligence that can create new forms of technology based on its superior ability to learn. These are the ideas that generate fear and apprehension as to just what such intelligence is capable of, when futurist speak of AI as the next nuclear weapon of our generation, the Military General AI may just be that weapon.

Are there Innovative Concepts for Implementation?

The general policy with regards to AI implementation revolves around efficient or better completion of established tasks or systems. Concepts are more often constrained to automation, and replacement (unmanned systems) but the scope for novel implementation is a matter of resourcing in both Civil and Military domains.

The United States Military stated a position on Automation and Artificial Intelligence is given by a number of strategic policy documents. The future force development for unmanned systems is contained in the Unmanned System Integrated Road Map 2013-2038. While provision is made for distinguishing between autonomous execution and mission performance, the later suited to AI integration, it does so from a perspective of hard-coded programs, in fact it states that the solutions are only as good as

the human programmer,[84] perhaps an oversight but as of 2013 the use of AI was not fully considered.

This is not always the case as in separate documentation the US Military has adopted a fairly rigid implementation strategy for autonomous and semi-autonomous systems the full details can be found in (Defence, 3000.09 Autonomy in Weapons Systems 2012) but it does guide development and application (potentially but not implicit) for AI.

Systems developed with 3000.09 must undergo rigorous hardware and software verification and validation to ensure functionality, complete engagements within a timeframe consistent with commander or operator intention, be sufficiently robust as to prevent unintended engagement.[85]

Systems must remain under the appropriate control of the human, with anti-tamper mechanism and human-machine interface controls.[86]

The systems must also be readily understandable by their operators so that informed decision can be made for engagements. This requirement mean that there must be a readily understandable interface, and the ability to trace or provide feedback on system status, including an ability for operators to easily activate and deactivate system functions.[87]

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[84] Department of Defence, *Unmanned Systems Integrated Roadmap*.

[85] Department of Defence, DoD Directive 3000.09.

[86] Ibid.

[87] Ibid.

Objectively the United States Military implementation injects ethical and legal restrictions on the development and use of autonomous weapon systems; the requirements adds additional developmental requirements to developers, in particular, if the AI that is making decisions needs to be explained beyond conceptual description. As we know from earlier machine learning, the object is not to constrain how the AI solves the problem, just that it can provide a useful output.

For the time being AI sits most squarely in the research and development phase of acquisition and it is to DARPA that we can gain an idea of some of the implementation concepts for military AI.

As DARPA works closely within the remit of policy direction, the disclosed projects at DARPA exhibit strong influence from the restrictive policy. The Explainable AI[88] project aims to make the output or decisions of an AI comprehensible to an operator, which services the requirements of 3000.09.

A second notable project; Probabilistic Programing for Advanced Machine Learning[89] which has been running since 2013, is designed to broaden the depth of talent that can be employed in ML research and development. The problem with AI and

[88] David Gunning, "Explainable Artificial Intelligence (XAI)," Defense Advanced Research Projects Agency, accessed April 1, 2017, http://www.darpa.mil/program/explainable-artificial-intelligence.http://www.darpa.mil/program/explainable-artificial-intelligence.

[89] Dr. Jennifer Roberts, "Probabilistic Programming for Advancing Machine Learning (PPAML)," Defense Advanced Research Projects Agency, accessed March 28, 2017, http://www.darpa.mil/program/probabilistic-programming-for-advancing-machine-Learning.

implementation is that there are more projects than experts, and the projects require "herculean" effort to complete.

Probabilistic Programing for Advanced Machine Learning will make ML accessible to the non-expert programmer, of which it is significantly more available to develop new applications.

Is there a Drive for Organizational Adoption of Artificial Intelligence?

The automation and de-humanization in a very literal sense of military systems remain a question of policy. There are no indicators that suggest a shift in the size of military organizations as a result of future automation.

The most recent doctrinal publication the FM 3-0 which is expected to be published in October 2017, will introduce more fully the concepts of multi-domain battle and hybrid warfare to the operational context.

While Automation plays a big part in a discussion on future warfare, automation is not synonymous with the concept of AI. For example, in recent reporting the Armata T-14 tank has a fully-automated turret system. However, the reality is that the turret has been remoted to a commander and gunner inside the vehicle.[90] As a step towards full autonomy, it is significant but it does not yet have the capability to conduct autonomous engagements, these distinctions are important when having a robust discussion about the implementation of military AI.

[90] Tamir Eshel, "New Russian Armor–First Analysis: Armata," Defense Update, May 9, 2015, accessed March 30, 2017, http://defense-update.com/20150509_t14-t15_analysis.html.http://defense-update.com/20150509_t14-t15_analysis.html.

Without a clear distinction and understanding about the differing levels of autonomy and AI, the fact that the can exist together and independently has a significant bearing on the future development of a military application to AI.

CHAPTER 5

FINDINGS

Artificial Intelligence is neither an MR or RMA

The primary research question, Will Artificial Intelligence, cause a revolution in military affairs or a military revolution.

As there is no known General AI in the world today, and until one exist it is my belief that AI will not cause a Military Revolution. The rapid implementation of Narrow AI has the latent potential for RMAs across multiple domains however this too appears to be in incipient stages of development.

Explanation

A military revolution occurs outside of the military establishment, its genesis can be technical or cultural, but the changes wrought on culture, political, economic and social must intern generate significant pressure on the military to adapt, innovate and harness the energy of the revolution.

Smaller, but in many cases as significant for the military establishment, is the RMA. These are almost exclusively dependent on new technology, which can improve on, or introduce new systems for warfare, combined with tactical, technical and doctrinal innovation, with an organizational drive that exhibits a desire to integrate opportunity, for the express purpose of gaining a military advantage.

At the time of writing the known implementations of Artificial Intelligence are restricted to developments in the field of narrow or weak AI.

Within this context, AI has been implemented within the wider civilian environment for some years, and we have begun to see accelerated growth and discussion as it becomes more commonplace and powerful. No real change to any established social, economic, political order has been demonstrated as a result of AI implementation.

The development of AI in military domains is relatively new and limited in implementation. When compared to the core character of the RMA we can see demonstrated performance in two of four requirements. Narrow AI is driving technology change and development with numerous applications. It is capable of being implemented in weapon systems, but just as important wherever decision making must be performed; AI offers a pathway to faster, more efficient solutions. In this manner, it satisfies the second condition for an RMA, and that is widespread change over multiple systems.

Narrow AI in current policy, does not exhibit the drive for innovative implementation, policy maintains the primacy of human operators and control, which limits full implementation. The application of AI to automate systems is aimed at removing the risk to the human operator, rather than exploiting the potential gains of the non-human operator.

Finally, emerging doctrine has yet to embrace organizational change to implement AI and autonomous weapon systems. Minor unit structures and manning will be part of future force structure, but a system for fully automated battle has yet to be devised and experimented with.

The reason may be consistent with observations on innovation and adaptation, in that the present military climate and balance of power does not present a sufficient

external threat to the established order, allowing the implementation and policy of AI to evolve in a ponderous manner.

These observations are based on the Narrow AI research. The same cannot be said of the theoretical implications of a general AI. The effect of General AI is unknowable, it is just fundamentally not part of the human range of understanding, to think of this event as a potential black swan is highly reasonable.

If it were to happen, I would expect it to occur within one of the technologically advanced industrial nations, based on the experience of cumulative military revolution. However, if a digital computer is capable of hosting or implementing general AI, the tools for its development are ubiquitous, and the emergence could happen anywhere, if such a case were true, the idea of banning such a general AI is fundamentally flawed for the same reason, it would be impossible to enforce.

These findings are summarized about MR and RMA in the tables that follow and reflect the author's findings at the time of publication. Noting that this may change as development continues in both General and Narrow AI.

Table 1. Artificial Intelligence as Military Revolution

Table of MR Observations					
	Industrial	Nuclear MR	Information	General AI	Narrow AI
Does it change Politics	+ Working Class	++ Nuclear powers dominate international politics	+ Social Medial and globalization	Unknown	No
Does it change the Strategic context	+ Dominant countries	++ Yes	+ No	Likely to	No
Does it change Society	++ Mass movement to cities	+ Minor	++Yes	Likely to	+ Exploitation of Data
Does it change Economic	+++ Wealth Surplus	+ Cost is prohibitive	++ Yes financial institutions reliant on IT	Likely to	+ Yes
Does it change Technology	++ Production and new	+ Yes	+++ Yes	Likely to	++ Yes
Does it change how Military conducts warfare	++ Yes	++ Yes theoretically	++ Yes	Likely to	+ Incipient Stages
Does failure to adopt lead to socio-political disadvantage	+++ Yes	++ Yes	+ Yes	Yes	Unknown
Does it generate RMAs	+++ Yes	+ Yes	++ Yes	Likely to	++ Yes

Source: Created by the author.

Table 2. Artificial Intelligence as Revolution in Military Affairs

Table of RMA Observations		
	General AI	Narrow AI
Does the RMA consist of new technology?	No, Theoretical Only	Yes
Does the RMA have application over multiple systems?	Likely	Yes
Does the RMA have innovative doctrine, tactics or techniques?	Likely	No, Conceptual only and with restrictions
Does the RMA have Organizational Adoption?	Unknown	No
Does it make established warfare redundant?	Unknown	Not without widespread implementation
Does the RMA have a dominant domain?	Unknown	Yes, Cyber then in decreasing complexity for implementation Space, Air and Sea then Land

Source: Created by the author.

Further Research

Artificial Intelligence, while affecting many technologies is of itself a field of scientific research, one which crosses the usual divide between science and engineering. If one is to think of AI as a field rather than technology, it becomes apparent that the scope of research is vast, which implies huge potential to affect society, politics, economics and technology.

How does one implement and regulate a technology that is already distributed and accessible? In particular, what threat does the technology pose to a nation, or military that arrives late to the capability?

What secondary efforts in the field may significantly impact the conduct of war, the scope of this technology is vast, with applications across multiple fields, it is possible that developments may manifest as a series of rapid revolutions in military affairs across different arms, within differing regions and national interests.

Does the technology pose an existential threat to humanity, and should military and nation states contemplate preemptive action to limit its development or application, and if the answer is yes is it even possible to regulate?

What good is the current United States policy on development and implementation of autonomous weapons if the adversaries in the world have access to as good or better tech, and a will to develop weapon systems without ethical restrictions?

How do we raise a new generation of soldier, and officers that are comfortable with, and understand how and implement AI can make better decisions and win in combat.

In thinking of AI in military terms do we limit the potential for positive human development as a result of AI research? Can a general AI that manifests a wider social-military revolution stop the cycle of innovation and adaptation and make warfare either redundant or too costly to contemplate, is it possible to final remove the human from Clausewitz Trinity and disrupt the enduring nature or war?

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